TITLE: Considerations on Information Overload in Electronic Warfare

TITLE: Usability of Information in Battle Management Operations [1'Exploitation de l'information dans les operations de gestion du champ de bataille]

CONSIDERATIONS ON INFORMATION OVERLOAD IN ELECTRONIC WARFARE

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Summary: This paper presents some considerations regarding the information overload in electronic warfare, focusing on land-based tactical electronic systems. After a quick review of signal environment and signal processing tasks in electronic warfare, two particular cases are presented: emitter identification and evaluation & reporting. For these two cases, some solutions to reduce information overload are considered.

Signal Environment on the Battlefield

The improvements in electronics and computer technologies have made the number of emitters, both civilian and military, increase dramatically. As a consequence, we are facing now a very dense signal environment. The expansion of signals occurs either in space (ground, sea, air and satellite emitters) or in frequency (expansion to the higher frequency bands). Furthermore, the signals in the classical frequency bands have become more complex from the point of view of modulation, coding and other parameters.

By definition, the *signal environment* consists of all the signals that reach the antenna of a receiver, within the frequency band covered by that receiver. Therefore, not only the signals of interest will build up the signal environment on the battlefield, but also the signals from friendly forces, neutral forces and many signals from civilian systems operating in the frequency band of the receiver.

All these signals can be a target for electronic warfare systems, which act to reduce or prevent the hostile use of electromagnetic spectrum, and ensure its effective use by friendly forces. There are many classification criteria used by electronic warfare to divide the signals of interest in different categories, but I think the most suitable for our purpose is the classification criterion based on the destination of the emitter. Using this criterion, the most common types of signals are:

- radio and radio-relay signals
- radar signals
- satellite signals
- mobile telephone signals
- other type of signals

Radio signals can be described by a set of parameters like: frequency, bandwidth, amplitude, modulation etc. Special types of radio signals like frequency hopping signals are described by special parameters: hopping rate, hopping bands, dwell time etc.

Radio-relay signals usually allow transmission of information using more than one channel, therefore an additional parameter can be the number of channels.

Radar signals are generally described by a general set of parameters: frequency, pulse repetition frequency, pulse width and scan rate. Particular types of signals (stagger, jitter, pulse and CW Doppler) need special parameters to be defined.

Satellite signals have become a target for electronic warfare on the tactical field since the satellite tactical systems were extensively used during the latest conflicts. Up-link frequency, down-link frequency, amplitude, polarization, type of information – data, fax, voice – can be only a few parameters to describe the signal.

Mobile telephone signals. Even the signal from a mobile telephone is weak and has a limited range, it complicates very much the signal environment, because of the great number of cellular phones within the area, and the special type of the signal. This mainly applies to low intensity conflicts or special operations taking place in populated areas. Usually, the mobile telephones are not a threat for military systems, but they need to be dealt with, in order to have a accurate picture of the threat

Electronic Warfare Processing Tasks

As we have seen in the previous section, electronic warfare systems have to respond to a very broad band of threats. Therefore, the processing of the information concerning the threat is necessary, before taking the appropriate decision or countermeasure.

The diagram of the processing tasks in a tactical electronic warfare system used for communication

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systems is presented in Figure 1. Each task is described in Table 1.

Processing Task	Role
Search	Continuously scan a designated frequency band in order to detect the threat
Identify	Identify the emitter type by matching the parameters of the threat to the parameters of the library
Intercept	Receive signals from the emitter
Monitoring & Recording	Listening, carrying out surveillance on and/or recording of a particular emitter.
Direction finding	Detection of the bearing of the emitter
Localization	Calculation of the emitter position using two bearings at least
Analysis	Accomplishes the thorough analysis of the signals, mainly for unknown and scrambled signals
Sensor/Data Fusion	Correlate data from multi-source information
Evaluation & Reporting	Evaluates all the searching, DF and analysis reports and issues the Electronic Order of Battle
Jamming	Neutralize the assigned threat

Table 1 Processing tasks and roles for an EW System

The systems accomplishing these tasks are very complex and diverse. A single operator can accomplish one or more tasks. All tasks can be remote controlled, and some can be performed automatically. Search, direction finding, localization, recording can be automatically accomplished. However, for each task the system needs the input from the operator and outputs data to the operator. Some tasks, like emitter identification, analysis, evaluation and reporting need the intervention of an operator, at least to validate the results.

It is beyond the purpose of this paper to present different solutions for data acquisition and processing in electronic warfare systems. The nowadays technologies allow to build hardware equipment and software packages capable of reaching up to 10 GHz/s scanning speeds and instantaneous frequency bandwidth of several MHz in COMINT systems, and several millions of pulse/second capabilities in ELINT systems. These parameters, combined with others (increased sensitivities, large databases etc) allow EW systems to deal with low probability of interception signals, or other kind of exotic signals.

Studies performed on human factors showed that human capabilities have not developed at the same speed as technologies. Training an electronic warfare operator is not so easy, and training a crew is even more difficult, because of the differences among the crewmembers.

One of the most important missions of the electronic warfare is to detect and warn of threats – that means real time reaction. We can reason that the most critical tasks in electronic warfare systems are the tasks that cannot be performed fully automatically using computers and need fast reaction times. Two of them are emitter identification and evaluation & reporting tasks. Let's analyze them one by one.

Emitter Identification

There may be hundreds of radio emitters, dozens of radar emitters and other kind of emitters on the battlefield. Each emitter can have several working modes. If a piece of equipment tried to deal with everything on the battlefield without prior preparation, it would be surely overloaded by the considerable amount of data, no matter how sophisticated is the electronic warfare equipment.

Therefore, every received signal has to be compared with the data stored in the library. If there is a match for enough parameters, the identification is accomplished. If not, the recorded signal is passed to the analysis operator that will have a closer look, using more precise tools and more parameters. These operations are not as simple as they look, because comparison is not always so easy to make. There is an ambiguous nature of the parameters. Sometimes, a tracking radar in the searching mode looks like a navigation radar on the screen. For a pilot, that difference can be the difference between life and death. That's why the operator has to validate the process, after the computer performs the comparison.

The computer plays a major role in the signal identification algorithm, but computers and operators have a different approach to the information. Table 2 shows how they deal with the information flow.

FUNCTION	COMPUTER	HUMAN OP.
Input	Millions pulses/s Thousands of commms signals	Optical input Computer screen
Model function	Fixed format commands	A flexible way of thinking based on experience
Output	Binary data millions bits/s	keyboard (50-200car/min) mouse clicks (60/min) voice
Drawing conclusions	Very specific, based on precise inputs	Perception of the whole electronic environment (even when there is not enough data)

Table 2 Computer and human behaviour in EW data processing

The first and last characteristics are very important when we speak about signal identification. Humans can accept incomplete data and compile it to achieve the complete situation picture. Whenever there is a slight difference between the detected and stored parameters the operator has to decide whether a signal is to be associated with a type of emitter or another, particularly when the computer says there is not sufficient data to give a single and acceptable solution.

Another question is how to avoid the limitation imposed by the limited number of signals that can be processed by the eye of the human operator. In other words, how can an operator identify the dynamic representation of a particular signal on a very cluttered screen. The example shown in the Figure 2 represents a hypothetical screenshot of the signal environment on the tactical battlefield, taken by a fast direction finder system. The receiver system allows the interception of all types of signals including the agile ones. The hints (interceptions) are directly represented on the screen for interpretation and identification. There are about 200 hints from about 50 emitters. It is very difficult for an operator to make the distinction among fixed frequency, frequency hopping, burst and other types of signal. Only a very skilled operator can separate some signals and identify the type of emitter and there is a significant probability of error.

What can be done to help the operator? First of all, the clutter represented by multi-path, mirror and other random signals can be cleared-out using statistic criteria. Secondly, the fixed frequency signals can be isolated using their constant parameters and represented on the screen (white colour). The frequency hopping signals are separated using the bearing information (a significant number of hints with different frequencies are detected on the same bearing -painted in yellow). The rest of signals can be bursts (black) or other types (mobile phones signals, radio-relay signals or unknown). Specific missions require specific signal discrimination algorithms, therefore the process described above has to be very flexible.

After the signal is processed, different types of signals will be represented in different ways on the screen, as you can see in the Figure 3. This will make the life of the operator significantly easier. This way he can concentrate on using his skills to give the solution in case of inconsistency of data. The areas of the screen designated by the numbers 1 and 2 may represent one or two frequency-hopping signal in each case. In the first case the operator has to decide if there are signals from two hoppers close to each other or only from one hopper with some reflections. Similarly, in case 2, there could be two hoppers or a single hopper using two sub-bands.

Evaluation & Reporting

Another critical task in the processing flow is evaluation & reporting. The information received from different component of the integrated system is correlated using also data from other systems and sources and the resulted information is used to elaborate reports for military commanders. According to the Army Field Manual FM 101-5: "*Army operations produce tremendous volume of information. Much of this information is useful, but not pertinent, to the commander, during decision making. Commanders and staff who understand this can avoid potential information overload by using* *effective systems to accurately and rapidly convey information".*

So, only the critical information for the decision making is required during the battle. As the main functions of electronic warfare are to detect, warn of threats and self-protect, a certain amount of EW information is critical for the commander and staff.

Electronic Order of Battle (EOB) is a visualization application, showing in real time the emitters of interest, their level of interest or threat, the allocation of EW resources and the tactical interpretation of the results. Other information of interests, such as the deployment of own troops, communication networks can be also represented. The tactical situation is presented using geographical features as background. Figure 4 presents an example of a simple EOB, using a digital map and an embedded library of symbols. Using a VHF direction finder baseline, close to the Forward Line of Own Troops, the command radio network of the enemy is identified, Brigade HQ and Company HQs were placed on the electronic map.

It is obvious that representing any detail of the tactical situation on an electronic map with plenty of geographical details will make the EOB difficult to read and interpret. There is a practice of using existing software products (former reports, situation displays etc.) and adding new facts and analysis. The result is much more overcrowded picture, with only a small part of information being useful. It is essential that only the up-to-date information be rendered in the report.

Another important problem of EOB is the appearance and options for the geographical features. Sometimes, you need some geographical features to be underlined, while others are obscuring the tactical information.

One solution to the problem is the Geographical Interface Systems (GIS), which use databases to store the geographical data. Digital Chart of the World, (DCW), Digital Terrain Elevation Data (DTED), and VMAP are only a few standards used for digital maps with GIS. Figures 5 and 6 represents a simple comparison, showing the advantages of using a GIS package to generate EOB situation displays.

The example starts from the same picture, representing a shape (ARCVIEW) file, in the Figure 5 (left side). Because the files were exported for the purpose of this presentation, there seems to be no improvement in appearance for a shape file, but in fact it can be loaded faster and require a smaller amount of memory. As geographical information in the shape file is organized in a database any report, graph, diagram or table containing geographical and tactical data is relatively easy to build. You can search for a particular village on the map using its name, you can find distances using mouse clicks, or you can select the peaks having a certain height with road access to install your sensors. There are many displaying possibilities.

Zooming in a bitmap EOB can be a nightmare, while zooming a shape image preserves the clarity and require less time. The comparison is presented in the two pictures from the middle.

The shape maps are organized on layers. One can activate only the useful layer (only one mouse click can activate or hide a layer). The top and bottom right pictures represent the same basic situation. In the top right picture the EOB use only two geographical layers: river and population. In the bottom right side of the screen a new layer was added -railways. The tactical data can be also organized on layers. Labeling allows you to put only the relevant names on the map, by using mouse clicks (in this case only the names of towns and villages close to the military headquarters).

Conclusions

Some practical conclusions can be drawn, based on the above considerations:

- There is an increasing use of computers in processing electronic warfare information on the battlefield in order to surmount the problem of increasing quantity of data, but this does not mean the operators will be completely eliminated from the system. The computers will support the limited human capability regarding input and output data and people will use their flexible thinking to cover the whole situation. This is the way to overpass the information overload

- Visualization technology will continue to be an important issue in electronic warfare, because the people who is involved in decision making is not getting smaller. There are a lot of situations where people need to assess, identify, make interpretation and decisions. Visualization is one of the main ways to prevent information overload.

The standard picture, with an operator in front of a receiver, turning knobs and looking narrow screens is no longer valid. The new technologies, such as VXI, implemented the standard computer interface as human-machine interface in electronic warfare. This allows mission-driven configuration of the EW systems and requires less time to train the operators.

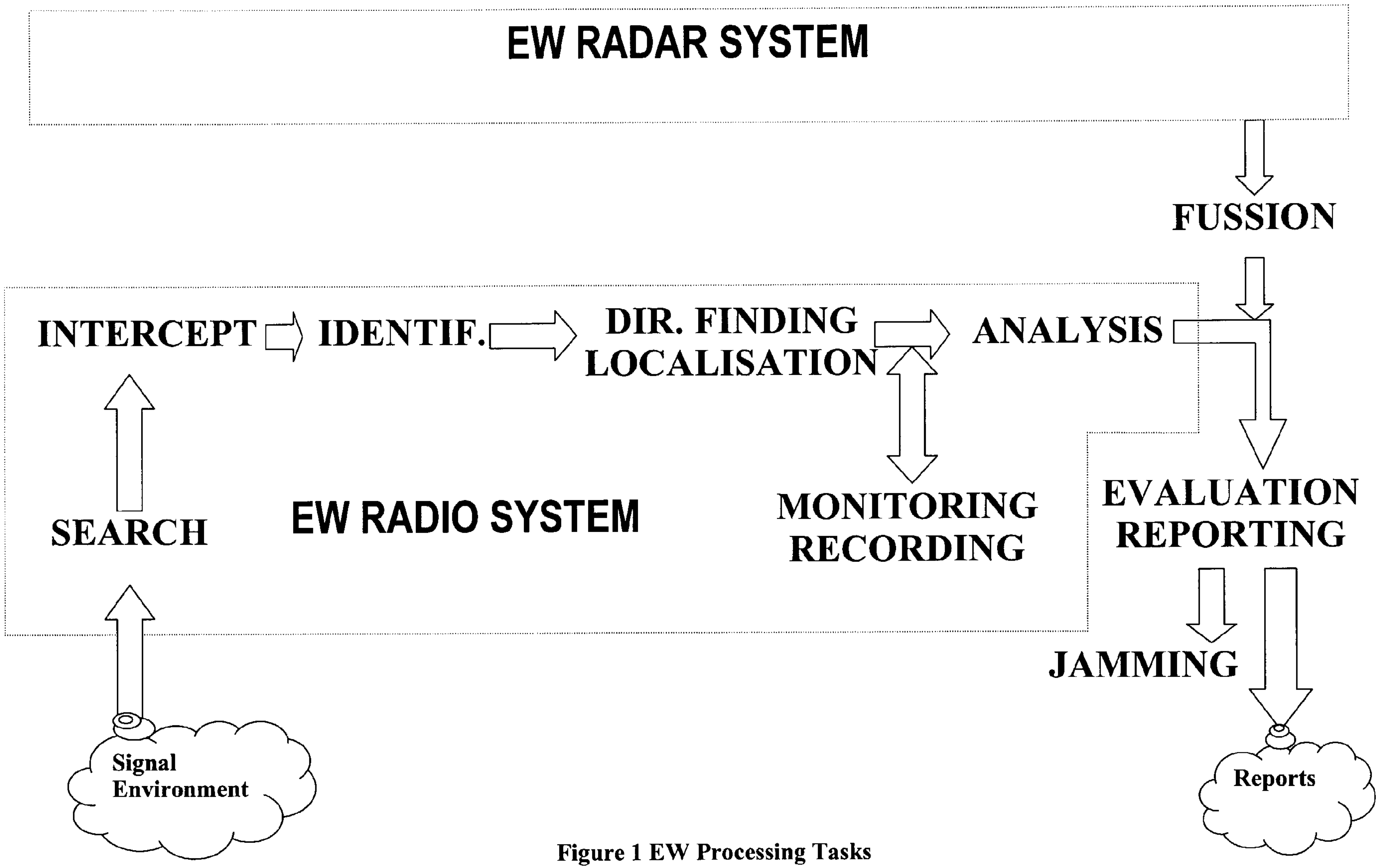


Figure 1 EW Processing Tasks

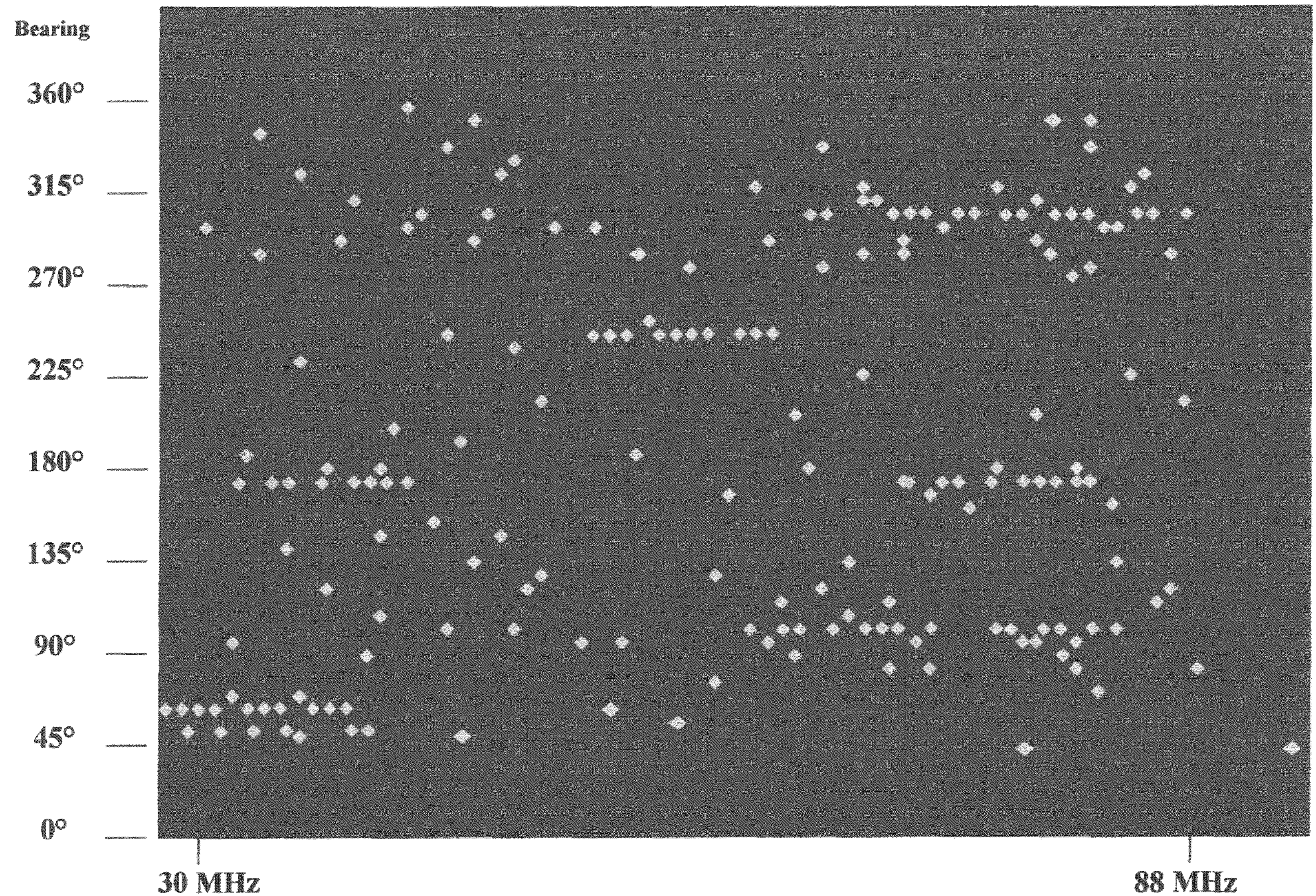


Figure 2 Signal identification without classification

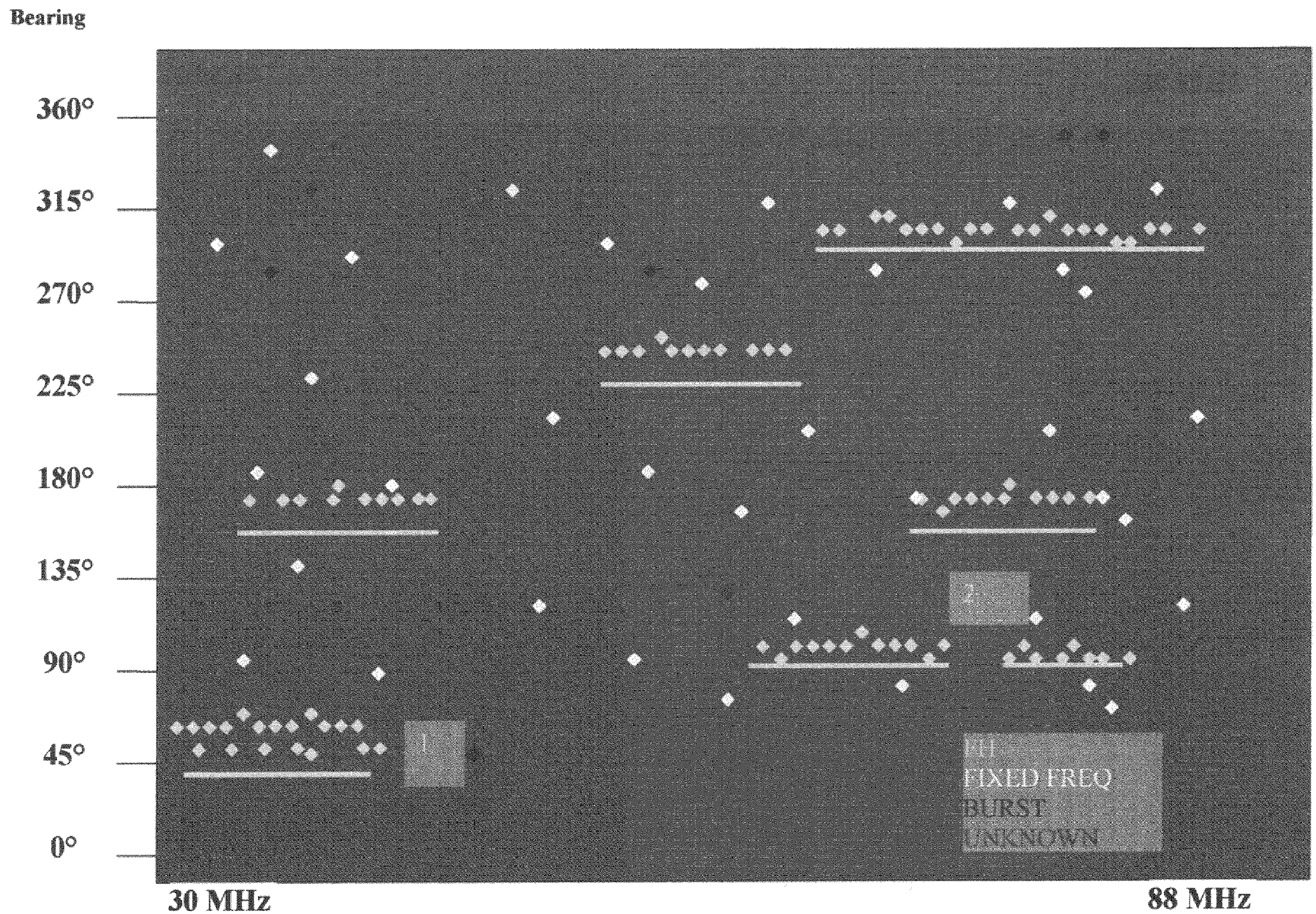


Figure 3 Signal identification after classification

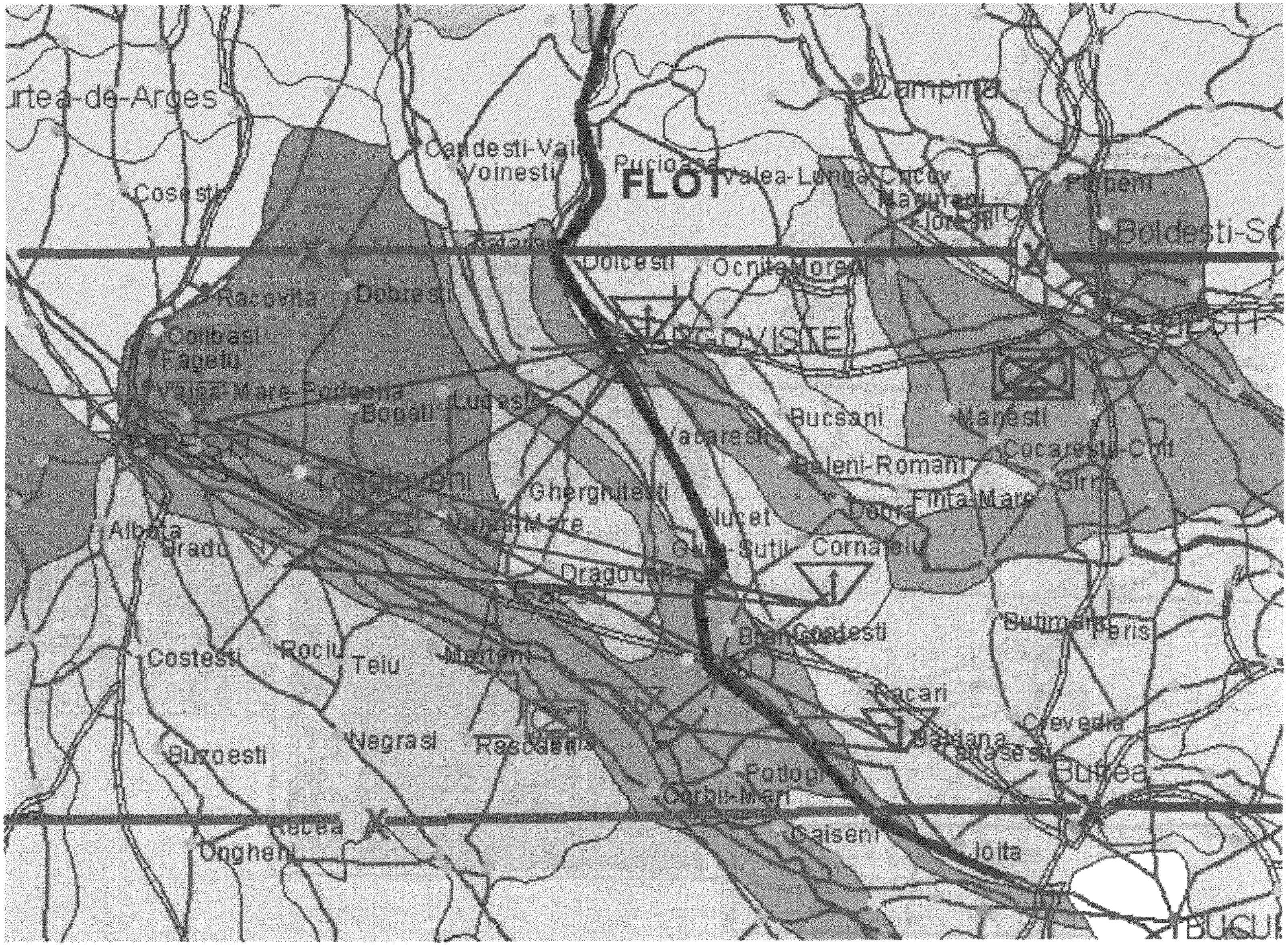
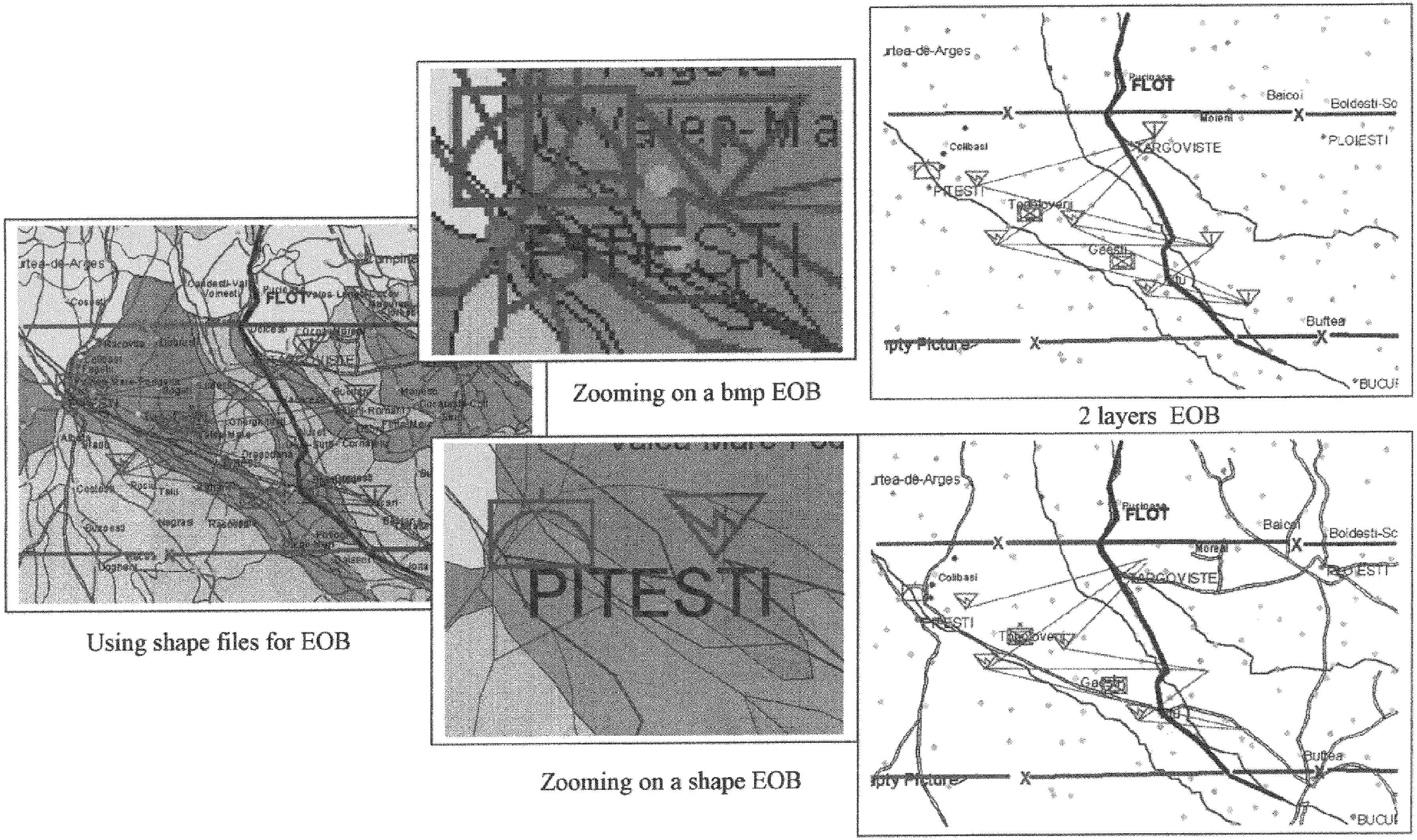


Figure 4 Electronic Order of Battle



Using shape files for EOB

Zooming on a bmp EOB

Zooming on a shape EOB

2 layers EOB

3 layers EOB

Figure 5. Building EOB using shape files